**Associations between meeting combinations of 24-hour movement recommendations and dietary patterns of children: A 12-country study**

Running Head: 24-hour guidelines and diet in children

*Original Research Paper*

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**Abstract**

The purpose of this study was to examine whether meeting movement behavior recommendations (i.e., ≥60 minutes of moderate-to-vigorous physical activity [MVPA] per day, ≤2 hours of recreational screen time per day, and between 9 and 11 hours of nightly sleep), and combinations of these recommendations, are associated with dietary patterns of children. This cross-sectional study was conducted between 2011 and 2013 and included 5873 children 9-11 years of age from 12 countries around the world. MVPA and nightly sleep duration were measured using 24-hour waist-worn accelerometry. Screen time habits were assessed via self-report. A food frequency questionnaire was used to assess dietary patterns, and the whole diet was described by two components derived from principal component analysis: “healthy” and “unhealthy” dietary pattern scores. Covariates included in the multilevel statistical models included age, sex, highest parental education, and body mass index z-score. A healthier dietary pattern score was observed when more movement behavior recommendations were met. Among the three movement behaviors, limiting screen time habits to the recommended amount was most strongly associated with healthier dietary patterns. Similarly, a less unhealthy dietary pattern was observed when more movement behavior recommendations were met. Surprisingly, the highest unhealthy dietary pattern was associated with children meeting the MVPA recommendation alone. Combinations including ≤2 hours of screen time per day were those most strongly associated with a less unhealthy dietary pattern. Findings were similar across study sites and in boys and girls. In conclusion, meeting more movement behavior recommendations is generally associated with better dietary patterns in children from around the world, with limiting screen time habits showing the strongest relationships.

Key words: physical activity, screen time, sleep, diet, food intake, eating behavior, pediatric

## Introduction

High physical activity, low screen time, and sufficient amounts of sleep (defined in this paper as "movement behaviors") are all important for overall health in children [1-3]. It is recommended that school-aged children spend ≥60 minutes per day in moderate-to-vigorous physical activity (MVPA), engage in ≤2 hours per day of recreational screen time, and sleep between 9 and 11 hours per night to promote health [4-6]. We have recently shown that meeting all three recommendations of movement behaviors corresponds with the lowest odds ratio for obesity in children, while meeting two recommendations is better than meeting one, and meeting one is better than meeting none [7]. These findings and others[8-10] suggest that the whole day matters from a movement continuum perspective, and encouraging optimal levels of MVPA, limiting recreational screen time, and obtaining an adequate amount of sleep is important for the prevention of obesity in children.

Studies have reported that low levels of physical activity[11], high levels of screen time[12], and short sleep durations[13] are all associated with increased food intake and poor diet quality in children. Thus, a key mechanism by which insufficient MVPA levels, high screen time levels, and insufficient sleep durations may lead to excess weight and obesity is through suboptimal dietary patterns. Yet, it is largely unknown whether meeting all or certain combinations of the movement behavior recommendations is associated with better dietary patterns of children than meeting only single behaviors. This information is important for future interventions and clinical and public health guidelines aimed at preventing childhood obesity. The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) is uniquely positioned to address this research question because it includes countries from around the world at differing levels of economic and human development. Indeed, data from ISCOLE permit us to test whether the associations among the behavioral recommendations are consistent across countries differing widely in human and economic development. Data establishing common associations among movement behaviors and eating patterns are important for the development of future interventions and clinical and public health guidelines.

The purpose of this study was to examine the associations between meeting recommendations for individual and combinations of 24-hour movement behaviors and dietary patterns of children from low- to high-income settings, and determine whether the associations vary by study site. We hypothesized that meeting a greater number of movement behavior recommendations would be associated with healthier (and less unhealthy) dietary patterns, irrespective of geographic location or country socioeconomic situation.

## Methods

### Study Design and Setting

ISCOLE is a multinational, cross-sectional study designed to examine the relationships between lifestyle behaviors and obesity in 12 countries from all inhabited continents of the world (Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, United Kingdom, and United States). ISCOLE study sites were chosen because they represent a wide range of human development index, economic development, and income inequality. More information about the design and methods of ISCOLE can be found elsewhere[14]. Children from urban and suburban areas only (n=256 schools in total) were recruited in ISCOLE in order to facilitate comparisons across sites and for logistical reasons. Data collection occurred between September 2011 and December 2013 and was conducted during the school year. A standardized protocol was followed for data collection to insure data quality, including rigorous training and certification of the personnel involved. The study was approved by the Pennington Biomedical Research Center Institutional Review Board as well as Institutional/Ethical Review Boards at each participating site. Parents/legal guardians gave their written informed consent, and child assent was also obtained.

### Participants

ISCOLE included 9-11 year-old children, and each site aimed to recruit a sex-balanced sample of at least 500 children. Of the 7372 children who participated in ISCOLE, a total of 5873 remained in the present analytical sample. Reasons for exclusion included invalid accelerometry data (n=1214) and missing information about screen time (n=25), level of parental education (n=255) and body mass index (BMI) z-scores (n=5).

**Measurements**

*Dietary Patterns*

A food frequency questionnaire (FFQ), adapted from the Health Behaviour in School-aged Children Survey[15,16], was used to assess dietary patterns of children. The FFQ queried about usual consumption of 23 different food groups, with seven possible response options: “never”, “less than once a week”, “once a week”, “2-4 days a week”, “5-6 days a week”, “once a day every day”, and “more than once a day”. The FFQ used in this study has been shown to be reliable (r=0.52-0.82) in children[17]. Dietary patterns of children were examined using principal components analyses (PCA) as reported previously[16]. The two strongest components were used for analysis: “healthy dietary pattern” (positive loadings for vegetables, fruit, whole grains, low-fat milk, etc.) and “unhealthy dietary pattern” (positive loadings for fast food, soft drinks, sweets, fried food etc.). The component scores were standardized to ensure normality, such that higher values represent either a “healthier” or “unhealthier” dietary pattern, respectively. It should be noted that each participant received a score for both components; hence, any combination of the healthy and unhealthy dietary pattern is possible. Country-specific component scores were used for this analysis.

*Movement behaviors*

MVPA was assessed with the use of an Actigraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) worn on the waist. Children were instructed to wear the device 24 hours per day (except for water-related activities) and for a period of at least 7 days (including 2 weekend days). The average wear time in this study was 22.8 hours per day. We included in our analyses only children with at least 4 days of waking wear time with at least 10 hours per day (including at least one weekend day). Data were downloaded in 1-s epochs using the ActiLife software and were later reintegrated to 15-s epochs to determine MVPA levels.

Sleep duration was assessed using 60-s epochs and with the use of an automated algorithm validated for this study[18]. The algorithm has been shown to provide more precise estimates of sleep duration than previous ones based on 24-hour accelerometry[18,19]. To be included in this analysis (i.e., valid sleep duration), 3 days of valid sleep were required (≥160 min/night), including at least one weekend night. MVPA was then defined as ≥574 counts/15 s after the exclusion of sleep period time and awake non-wear time (defined as any sequence of ≥20 consecutive minutes of zero activity counts)[20].

Screen time was self-reported by children using a lifestyle questionnaire[14]. Questions on screen time came from the US Youth Risk Behavior Surveillance System[21] and asked about time watching TV, playing video games and using the computer on weekdays and weekends (response options: 0, <1, 1, 2, 3, 4, and 5 or more hours). We calculated a daily average screen time score by weighting the responses (2/7 for weekend and 5/7 for weekday) and computing '<1' to '0.5' and '5 or more hours' to '5'. As previously reported, self-reported screen time assessments show acceptable validity and reliability in children[22,23]. Meeting the movement behavior recommendations was defined as ≥60 min/day for MVPA, ≤2 h/day for screen time, and between 9 and 11 h/night for sleep duration[4-6].

*Covariates*

Statistical models included age, sex, highest level of parental education, and BMI z-score as covariates. Age and sex were recorded on a questionnaire. Highest level of parental education was also self-reported and three categories were created: "did not complete high school", "completed high school or some college", or "completed bachelor's or postgraduate degree". This was based on the highest level of education attained by either parent. Standing height and body weight were objectively measured using standardized procedures[14] and BMI (kg/m$^2$) was calculated. Age- and sex-specific BMI z-scores were computed using the World Health Organization criteria[24].

**Statistical Analysis**

Descriptive characteristics (means and standard deviations) were computed by study site. Dietary patterns of children (healthy and unhealthy dietary pattern scores) were compared according to the combination of movement behaviors using an analysis of covariance with adjustment for covariates. Multilevel linear mixed model analysis (PROC MIXED) was used to investigate the differences in dietary patterns between children who meet and those who do not meet the different combinations of recommendations (fixed effects for study sites and random effects for schools). The Kenward and Roger approximation method[25] was used to calculate denominator degrees of freedom for statistical tests pertaining to fixed effects. The level of significance was set at $p<0.05$. Statistical analyses were conducted using JMP version 14 and SAS version 9.4 (SAS Institute, Cary, NC, USA).

**Results**

Table 1 shows descriptive characteristics of the children. On average children spent 60.2 minutes/day in MVPA (from 44.8 minutes/day in China to 72.0 minutes/day in Kenya), 2.9 hours/day in screen time (from 2.0 hours/day in India to 3.9 hours/day in Brazil), and 8.8 hours/night in sleep (from 8.3 hours/night in Portugal to 9.5 hours/night in the United Kingdom). We have not reported dietary pattern scores in the table as they are meaningless for descriptive purposes (by definition they have an overall mean of 0.00 ± 1.00 SD).

Findings from the multilevel models indicated that the largest proportion of total variance in healthy dietary pattern scores happened at the individual level (89%), followed by school (4%) and site (7%) levels. Similar findings were observed for unhealthy dietary pattern scores (individual, school, site: 63%; 11%; 26%). Overall, 19% of children met none of the recommendations, 44% met the MVPA recommendation, 39% met the screen time recommendation, 42% met the sleep recommendation, 17% met the MVPA + screen time combination, 18% met MVPA + sleep, 17% met screen time + sleep, and only 7% met all three movement behavior recommendations. We did not find significant sex interactions in the associations between combinations of movement behaviors and dietary patterns of children across sites. Boys and girls were therefore pooled together for analysis.

Figure 1 shows mean dietary pattern scores of children who meet the different combinations of movement behaviors in the full study sample. Overall, a healthier dietary pattern was observed with more movement behavior recommendations met (Figure 1A). Among the three single movement behavior recommendations, engaging in no more than 2 hours of screen time per day was the one more strongly associated with a healthier dietary pattern (even more so than meeting the MVPA + sleep duration recommendations together). With regard to unhealthy dietary patterns (e.g., fast food, fried foods, sweets, soft drinks), surprisingly, the unhealthiest dietary pattern was associated with meeting the MVPA recommendation alone, even more so than meeting none of the recommendations (Figure 1B). Of the three movement behavior recommendations, here again, meeting the screen time recommendation was most strongly associated with a better dietary pattern (i.e., less unhealthy dietary pattern).

Figure 2 also shows mean dietary pattern scores of children who meet the different combinations of movement behaviors in the full study sample, but using a bivariate graph. This figure allows to show the relative movement from the undesirable lower right quadrant (unhealthier dietary pattern) to the desirable upper left quadrant (healthier dietary pattern). This also shows how MVPA drags the scores to the unhealthy quadrant. Of interest, patterns of associations between dietary patterns and adherence with movement behavior recommendations were not different across study sites or by grouping of economic development (low, middle and high-income countries) (data not shown). This was also confirmed by the fact that there were no significant site interactions in the associations between movement behaviors and dietary patterns.

Table 2 shows dietary pattern scores in children meeting versus not meeting the movement behavior recommendations (and combinations), in the full ISCOLE sample. Children who met the screen time recommendation, the MVPA + screen time recommendation, the screen time + sleep recommendation, and all three recommendations had healthier dietary patterns than children not meeting these recommendations. The strongest association was seen when children met all three movement behavior recommendations, and limiting screen time habits to the recommended amount was most strongly associated with healthy dietary patterns. The unhealthiest dietary patterns were observed in children meeting the MVPA recommendation alone, while any combinations including limiting screen time habits were those more strongly associated with less unhealthy dietary patterns (i.e., children less frequently ate unhealthy foods if they met the screen time recommendation). Findings were also similar across study sites (data not shown).

## Discussion

To our knowledge, this study was the first to investigate the relationships between meeting various combinations of movement behaviors and dietary patterns in children from around the world. Collectively, we found that meeting more movement behaviors was generally associated with better dietary patterns of children. Among the three movement behaviors, meeting the screen time recommendation was the one most strongly associated with better dietary patterns. Similar associations between 24-hour movement behaviors and dietary patterns were found across sites and for boys and girls, suggesting that the present findings may apply broadly across different settings.

Our findings support current public health approaches by showing that meeting a combination of 24-hour movement guidelines is more likely to provide dividends than meeting single recommendations[7-10]. However, when looking at the associations with dietary patterns in children, the present findings suggest that limiting screen time habits to the recommended amount of no more than 2 hours per day is particularly important.

This observation is in line with current evidence demonstrating that screen media exposure leads to obesity in children via unhealthy eating behaviors while viewing[26]. Additionally, randomized controlled trials in community settings have shown that reducing screen time reduced weight gain in children, mainly via a change in eating behaviors[26]. It is thus not so surprising that eating behaviors of children would be better with less screen exposure in the present study. The greater challenge is to find ways to help the 61% of children exceeding the screen time recommendation, as found in our study. This is especially difficult in a context where screens have become so ubiquitous in today's world[27]. Effective interventions could include removing the TV and other screen-based devices from the bedroom of the children, setting limits on personal screen interactions, and actively engaging children in alternative behaviors[27].

An interesting finding of this study is the observation that MVPA was the movement behavior more strongly associated with an unhealthy dietary pattern in children from across the globe. This suggests that children engaging in ≥60 minutes of MVPA daily are more likely to eat unhealthy foods (e.g., fried foods, fast food, soft drinks) than children not meeting this recommendation. It is increasingly recognized that the relationship between physical activity and eating behavior is complex and shows a large inter-individual variability[28,29]. In some individuals, physical activity increases hunger and drives up food intake thereby offsetting the energy burnt through activity[28]. Some may even over-compensate in food (reward-driven eating behavior) for physical activities[28]. Unfortunately, the present findings cannot provide information about possible underlying mechanisms (only associations). However, it is not that surprising that active children eat more of everything (both healthy and unhealthy foods), because of their higher energy expenditure if they want to maintain energy balance.

Getting a sufficient amount of nightly sleep was the second movement behavior most strongly associated with better dietary patterns in this study. There is accumulating evidence for the idea that lack of sleep is a contributor to weight gain in children and that the main mediator is an increase in food intake[13,30]. Recent experimental studies also show that extending sleep duration in short sleepers facilitates appetite control and helps controlling body weight[31]. The present findings are consistent with this idea by showing that meeting the sleep duration recommendations was associated with better dietary patterns in children. The sleep + screen time combination was the one more strongly associated with less unhealthy dietary patterns. There is an important interrelationship between these two behaviors; screen time before bed has been shown to impact sleep and short sleepers are more likely to engage in screen time behaviors[13].

The present study included sites from countries having wide variation in levels of economic development, human development, and geographic dispersion. We did not find different patterns of associations between sites, suggesting that the reported findings may apply broadly to children from around the world. We also observed that the relationships between meeting combinations of movement behaviors and dietary patterns were not different between boys and girls. This suggests that interventions aimed at increasing adherence to 24-hour movement guidelines[4], at least as it relates to dietary patterns of children, could be generalized across different settings and demographic subgroups of the population.

Some strengths and limitations deserve attention. Important strengths comprise the large multinational sample of children, the wide geographic representation, the use of objective measurements whenever possible, and the highly standardized measurement protocol and rigorous quality control program[14]. The main limitations comprise the cross-sectional study design that precludes inferences about causality and temporality, the use of self-reported measures for dietary patterns and screen time, the lack of information about energy intake (kcal/day) or context, the limited generalizability of our findings to urban and suburban areas, and the possibility of residual confounding by variables not measured in ISCOLE such as mental health.

## Conclusions

Findings from this large multinational study of children show that meeting more movement behaviors was associated with better dietary patterns. In particular, meeting the screen time recommendation is the one most strongly associated with desirable dietary patterns of children. Findings were similar in boys and girls and across study sites, strengthening the generalizability of our findings. Future work should aim to find innovative ways to reduce screen time of children or to mitigate the suboptimal eating behaviors linked with screen media use.

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## Conflicts of interest

None

## Authorship

D.T. and J.-P.C. conceptualized and designed the study, carried out the statistical analyses, and drafted the manuscript. M.S.T., P.T.K., M.F., G.H., C.M., J.M., T.O., O.L.S., M.S., C.T.-L. and J.-P.C. conceptualized and designed the study. P.T.K. obtained funding. All authors critically revised the manuscript, approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

**References**


1. Poitras VJ, Gray CE, Borghese MM *et al.* (2016) Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S197-S239.
2. Carson V, Hunter S, Kuzik N, *et al.* (2016) Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S240-S265.
3. Chaput JP, Gray CE, Poitras VJ *et al.* (2016) Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S266-S282.
4. Tremblay MS, Carson V, Chaput JP *et al.* (2016) Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S311-S327.
5. World Health Organization. *Global Recommendations on Physical Activity for Health.* Geneva, Switzerland: World Health Organization, 2010, p.58.
6. Hirshkowitz M, Whiton K, Albert SM *et al.* (2015) National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep Health* **1**, 233-243.
7. Roman-Viñas B, Chaput JP, Katzmarzyk PT *et al.* (2016) Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. *Int J Behav Nutr Phys Act* **13**, 123.
8. Saunders TJ, Gray CE, Poitras VJ *et al.* (2016) Combinations of physical activity, sedentary behaviour and sleep: relationships with health indicators in school-aged children and youth. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S283-S293.
9. Carson V, Tremblay MS, Chaput JP *et al.* (2016) Associations between sleep duration, sedentary time, physical activity, and health indicators among Canadian children and youth using compositional analyses. *Appl Physiol Nutr Metab* **41**, Suppl. 3, S294-S302.

10. Janssen I, Roberts KC, Thompson W (2017) Is adherence to the Canadian 24-Hour Movement Behaviour Guidelines for Children and Youth associated with improved indicators of physical, mental, and social health? *Appl Physiol Nutr Metab* **42**, 725-731.
11. Beaulieu K, Hopkins M, Blundell J *et al.* (2016) Does Habitual Physical Activity Increase the Sensitivity of the Appetite Control System? A Systematic Review. *Sports Med* **46**, 1897-1919.
12. Thivel D, Tremblay MS, Chaput JP (2013) Modern sedentary behaviors favor energy consumption in children and adolescents. *Curr Obes Rep* **2**, 50-57.
13. Chaput JP (2016) Is sleep deprivation a contributor to obesity in children? *Eat Weight Disord* **21**, 5-11.
14. Katzmarzyk PT, Barreira TV, Broyles ST *et al.* (2013) The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): design and methods. *BMC Public Health* **13**, 900.
15. Currie C, Gabhainn SN, Godeau E *et al. Inequalities in Children's Health: HBSC International Report from the 2005/2006 Survey.* Health Policy for Children and Adolescents, No. 5; WHO Regional Office for Europe: Copenhagen, Denmark, 2008.
16. Mikkilä V, Vepsäläinen H, Saloheimo T *et al.* (2015) An international comparison of dietary patterns in 9-11-year-old children. *Int J Obes Suppl* **5**, S17-S21.
17. Vereecken CA & Maes L (2003) A Belgian study on the reliability and relative validity of the Health Behaviour in School-Aged Children food-frequency questionnaire. *Public Health Nutr* **6**, 581-588.
18. Barreira TV, Schuna Jr JM, Mire EF *et al.* (2015) Identifying children's nocturnal sleep using a 24-h waist accelerometry. *Med Sci Sports Exerc* **47**, 937-943.
19. Tudor-Locke C, Barreira TV, Schuna Jr JM *et al.* (2014) Fully automated waist-worn accelerometer algorithm for detecting children's sleep-period time separate from 24-h physical activity or sedentary behaviors. *Appl Physiol Nutr Metab* **39**, 53-57.

20. Evenson KR, Catellier DJ, Gill K *et al.* (2008) Calibration of two objective measures of physical activity for children. *J Sports Sci* **26**, 1557-1565.
21. U.S. Centers for Disease Control and Prevention. Youth Risk Behavior Surveillance System (YRBSS, 2012). Available at www.cdc.gov/HealthyYouth/yrbs/.
22. Lubans DR, Hesketh K, Cliff DP *et al.* (2011) A systematic review of the validity and reliability of sedentary behaviour measures used with children and adolescents. *Obes Rev* **12**, 781-799.
23. Schmitz KH, Harnack L, Fulton JE *et al.* (2004) Reliability and validity of a brief questionnaire to assess television viewing and computer use by middle school children. *J Sch Health* **74**, 370-377.
24. de Onis M, Onyanga AW, Borghi E *et al.* (1997) Development of a WHO growth reference for school-aged children and adolescents. *Bull WHO* **85**, 660-667.
25. Kenward MG & Roger JH (1997) Small sample inference for fixed effects from restricted maximum likelihood. *Biometrics* **53**, 983-997.
26. Robinson TN, Banda JA, Hale L *et al.* (2017) Screen Media Exposure and Obesity in Children and Adolescents. *Pediatrics* **140**, Suppl. 2, S97-S101.
27. LeBlanc AG, Gunnell KE, Prince SA et al. (2017) The ubiquity of the screen: an overview of the risks and benefits of screen time in our modern world. *Transl J Am Coll Sports Med* **2**, 104-113.
28. Blundell JE, Gibbons C, Caudwell P *et al.* (2015) Appetite control and energy balance: impact of exercise. *Obes Rev* **16**, Suppl. 1, 67-76.
29. Thivel D, Rumbold PL, King NA *et al.* (2016) Acute post-exercise energy and macronutrient intake in lean and obese youth: a systematic review and meta-analysis. *Int J Obes (Lond)* **40**, 1469-1479.
30. Chaput JP (2014) Sleep patterns, diet quality and energy balance. *Physiol Behav* **134**, 86-91.
31. Chaput JP & Dutil C (2016) Lack of sleep as a contributor to obesity in adolescents: impacts on eating and activity behaviors. *Int J Behav Nutr Phys Act* **13**, 103.

## Figure Legends

**Figure 1.** Healthy dietary pattern scores (**Figure 1A**) and unhealthy dietary pattern scores (**Figure 1B**) in children meeting the different combinations of movement behaviors in the full study sample (n=5873). Data are shown as adjusted means and standard errors of the mean. Means are adjusted for age, sex, highest level of parental education, and body mass index z-score. A significant main effect ($p<0.01$) was observed between meeting combinations of movement behaviors and dietary patterns. MVPA, moderate-to-vigorous physical activity; ST, screen time; SLEEP, sleep duration. Meeting the recommendations is defined as accumulating ≥60 min/day of MVPA, limiting recreational screen time habits to ≤2 h/day, and getting between 9 and 11 h/night of sleep. The study was conducted between 2011 and 2013.

**Figure 2.** Bivariate graph showing adjusted means of healthy (y-axis) and unhealthy (x-axis) dietary pattern scores of children meeting the different combinations of movement behaviors in the full study sample (n=5873). Means are adjusted for age, sex, highest level of parental education, and body mass index z-score. MVPA, moderate-to-vigorous physical activity; ST, screen time; SLEEP, sleep duration. Meeting the recommendations is defined as accumulating ≥60 min/day of MVPA, limiting recreational screen time habits to ≤2 h/day, and getting between 9 and 11 h/night of sleep. The study was conducted between 2011 and 2013.

**Table 1.** Descriptive characteristics of participants stratified by study site (n=5873).

| Country (site) | Participants (n, % males) | Age (years) | MVPA (min/day) | Screen time (h/day) | Sleep duration (h/night) |
|---|---|---|---|---|---|
| Australia (Adelaide) | 439 (46.5) | 10.8 (0.4) | 65.7 (23.1) | 3.0 (1.6) | 9.4 (0.7) |
| Brazil (Sao Paulo) | 435 (48.5) | 10.5 (0.5) | 59.3 (26.3) | 3.9 (2.1) | 8.6 (0.8) |
| Canada (Ottawa) | 502 (40.8) | 10.5 (0.4) | 58.5 (19.5) | 2.8 (1.8) | 9.1 (0.8) |
| China (Tianjin) | 463 (51.6) | 9.9 (0.5) | 44.8 (15.7) | 2.2 (1.5) | 8.8 (0.6) |
| Colombia (Bogotá) | 821 (49.1) | 10.5 (0.6) | 68.2 (24.9) | 3.0 (1.5) | 8.8 (0.8) |
| Finland (Helsinki, Espoo and Vantaa) | 434 (45.2) | 10.5 (0.4) | 70.4 (26.7) | 3.0 (1.5) | 8.5 (0.9) |
| India (Bangalore) | 526 (45.1) | 10.5 (0.5) | 48.5 (20.7) | 2.0 (1.2) | 8.6 (0.7) |
| Kenya (Nairobi) | 458 (45.4) | 10.3 (0.7) | 72.0 (31.3) | 2.5 (1.7) | 8.6 (0.9) |
| Portugal (Porto) | 578 (41.7) | 10.5 (0.3) | 55.3 (21.6) | 2.5 (1.4) | 8.3 (0.9) |
| South Africa (Cape Town) | 391 (39.3) | 10.3 (0.7) | 63.4 (25.4) | 3.3 (2.0) | 9.2 (0.7) |
| UK (Bath and North East Somerset) | 377 (43.0) | 10.9 (0.5) | 64.6 (22.8) | 3.2 (1.6) | 9.5 (0.7) |
| USA (Baton Rouge) | 449 (40.1) | 9.9 (0.6) | 50.1 (18.8) | 3.4 (2.2) | 8.9 (0.9) |
| *All sites* | 5873 (45.0) | 10.4 (0.6) | 60.2 (24.9) | 2.9 (1.7) | 8.8 (0.9) |

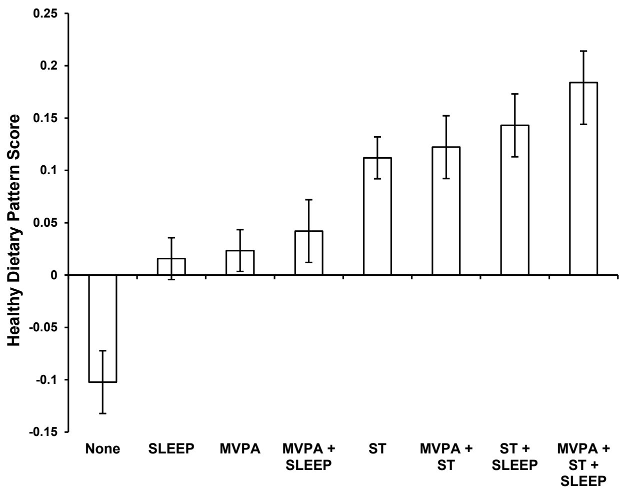
MVPA, moderate-to-vigorous physical activity.
Data are shown as mean (standard deviation) unless otherwise indicated.
MVPA and sleep duration were based on accelerometer data and screen time was self-reported.
The study was conducted between 2011 and 2013.

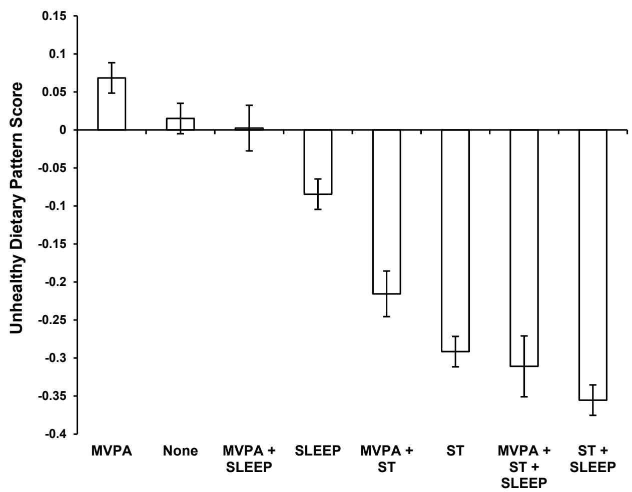
**Table 2.** Differences in dietary pattern scores between children meeting versus not meeting the moderate-to-vigorous physical activity, screen time, and sleep duration recommendations and combinations of these recommendations in the full study sample (n=5873).

| | *Healthy dietary pattern score* | | *Unhealthy dietary pattern score* | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| MVPA | | | | |
| Meet | 0.0235 | 1.0209 | 0.0684* | 1.0693 |
| Do not meet | -0.0124 | 0.9790 | -0.1350 | 0.8912 |
| ST | | | | |
| Meet | 0.1121* | 1.0185 | -0.2915* | 0.8377 |
| Do not meet | -0.0671 | 0.9778 | 0.1147 | 1.0297 |
| SLEEP | | | | |
| Meet | 0.0157 | 0.9965 | -0.0845* | 0.9474 |
| Do not meet | -0.0054 | 0.9987 | -0.0170 | 1.0003 |
| MVPA + ST | | | | |
| Meet | 0.1222* | 1.0528 | -0.2155* | 0.9114 |
| Do not meet | -0.0201 | 0.9849 | -0.0114 | 0.9884 |
| MVPA + SLEEP | | | | |
| Meet | 0.0420 | 1.0018 | 0.0024 | 1.0359 |
| Do not meet | -0.0052 | 0.9968 | -0.0560 | 0.9655 |
| ST + SLEEP | | | | |
| Meet | 0.1423* | 1.0240 | -0.3553* | 0.7866 |
| Do not meet | -0.0244 | 0.9902 | 0.0170 | 1.0018 |
| All three recommendations | | | | |
| Meet | 0.1844* | 1.0071 | -0.3109* | 0.8563 |
| Do not meet | -0.0108 | 0.9958 | -0.0243 | 0.9850 |

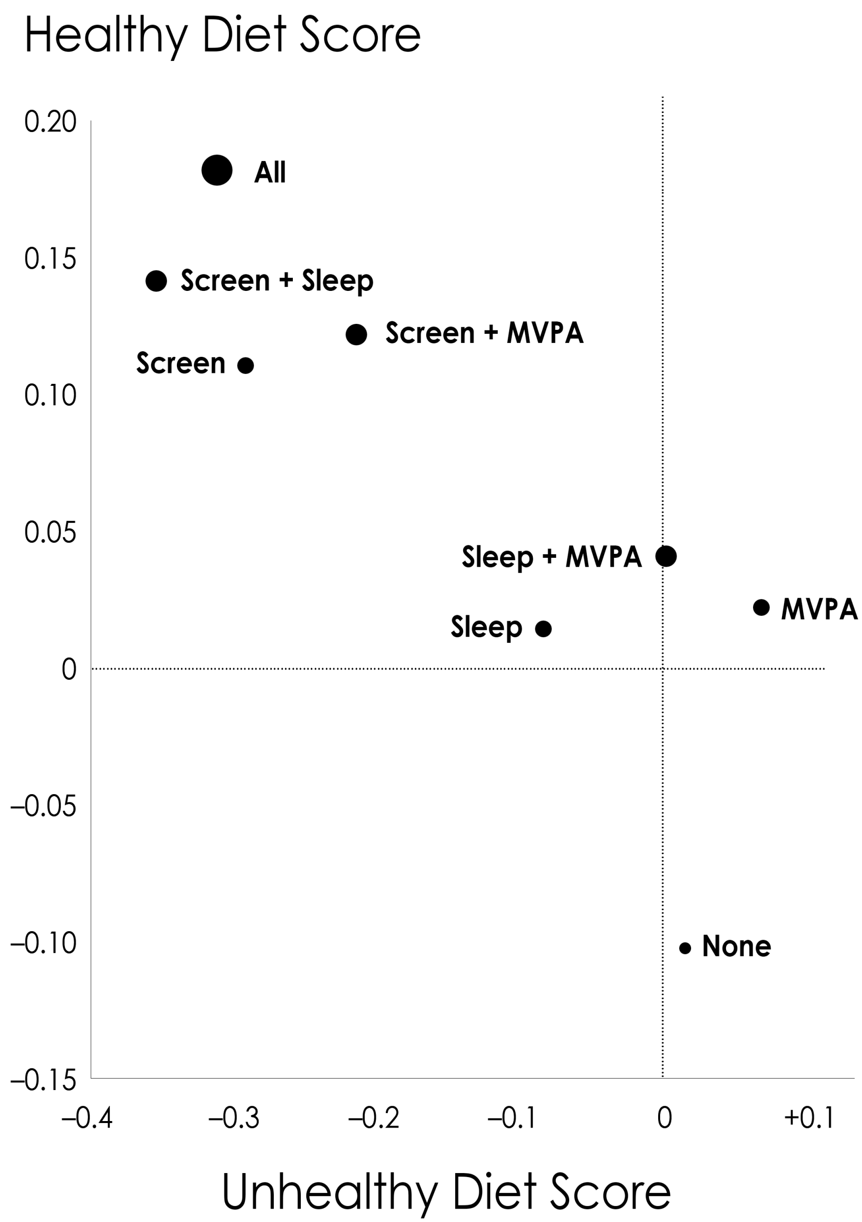
MVPA, moderate-to-vigorous physical activity; ST, screen time; SLEEP, sleep duration; SD, standard deviation.
Meeting the recommendations is defined as ≥60 min/day for MVPA, ≤2 h/day for recreational screen time, and between 9 and 11 h/night for sleep duration.
Models are adjusted for age, sex, highest level of parental education, and body mass index z-score.
Data are shown as mean (SD) of dietary pattern scores.
*p<0.001 versus do not meet the recommendation.
MVPA and sleep duration were accelerometer-determined while screen time was self-reported.

The study was conducted between 2011 and 2013.


Healthy Dietary Pattern Score
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
None
SLEEP
MVPA
MVPA + SLEEP
ST
MVPA + ST
ST + SLEEP
MVPA + ST + SLEEP



Unhealthy Dietary Pattern Score
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
MVPA
None
MVPA + SLEEP
SLEEP
MVPA + ST
ST
MVPA + ST + SLEEP
ST + SLEEP


Healthy Diet Score
0.20
0.15
0.10
0.05
0
–0.05
–0.10
–0.15
All
Screen + Sleep
Screen + MVPA
Screen
Sleep + MVPA
MVPA
Sleep
None
–0.4
–0.3
–0.2
–0.1
0
+0.1
Unhealthy Diet Score